Development of a Vertically Profiling, High-Resolution, Digital Still Camera System

Mark C. Benfield,
Louisiana State University
Department of Oceanography & Coastal Sciences/Coastal Fisheries Institute
218 Wetland Resources, Baton Rouge, LA 70803
phone (225) 388-6372 fax (225) 388-6513 email mbenfie@lsu.edu

Richard F. Shaw
Louisiana State University
Department of Oceanography & Coastal Sciences/Coastal Fisheries Institute
218 Wetland Resources, Baton Rouge, LA 70803
phone (225) 388-6734 fax (225) 388-6513 email rshaw@unix1.sncc.lsu.edu

Christopher J. Schwehm
Louisiana State University
Remote Sensing and Image Processing Laboratory
3221 CEBA, Baton Rouge, LA 70803
phone (225) 388-5262 fax (225) 388-5263 email chris@rsip.lsu.edu

Grant Number: N00014-98-1-0563
http://zooplankton.lsu.edu/zoovis.htm

LONG-TERM GOALS

Our scientific goal is to develop an improved capability for mapping the fine-scale horizontal and vertical distributions of mesozooplankton and other comparably sized particles in the oceans. Mapping of organisms in relation to environmental factors will help to understand the processes that lead to fine-scale patchiness. In-order to collect such biological and physical data, we require a system capable of quantifying zooplankton distributions and abundances on appropriate scales. A central component of this project is to develop a profiling instrument capable of collecting high-resolution images of zooplankton and other particles in the water column and concurrent environmental data on comparable spatial and temporal scales.

OBJECTIVES

1) To interface a high-resolution digital still camera, structured light source and environmental sensors with a surface control and acquisition computer;

2) To develop a graphical software interface to control the instrument; and

3) To evaluate the size distribution and abundance data generated by the profiling instrument in relation to a conventional multi-net (MOCNESS) system.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **Development of a Vertically Profiling, High-Resolution, Digital Still Camera System**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Louisiana State University,,Department of Oceanography & Coastal Sciences/Coastal Fisheries Institute,,218 Wetland Resources,,Baton Rouge,LA,70803**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

Development of the Profiling Instrument

Our zooplankton visualization and imaging system (ZOOVIS) consists of a 2048 x 2048 pixel digital still camera and a structured light strobe coupled to a CTD equipped with conductivity, temperature, pressure, optical transmittance, and fluorescence sensors. The underwater components include power distribution hardware and fiber-optic mode convertors and multiplexors. A fiber-optic interface on the camera provides the necessary bandwidth to transmit 12bit digital images to the surface at 2 Hz. The underwater unit is connected to the surface via an electro-optical oceanographic cable. Data from the camera and sensors and command and control flow bi-directionally via single-mode optical fibers while power is transmitted to the underwater unit via copper conductors. A surface winch equipped with a level-wind unit and an electro-optical slip-ring assembly controls payout and haulback of the underwater unit. Command and control are from a Pentium II PC running the Windows NT OS.

Mark Benfield with assistance from Richard Shaw is supervising the overall testing and development of the system while Chris Schwehm is the project's electrical engineer. Chris has worked directly with engineers at PixelVision Inc., and Nbase/Xyplex to develop the fiber-optic network used in our system.

Evaluation of System Performance

ZOOVIS has been assembled and is currently undergoing benchtop laboratory testing at LSU. These tests have quantified the system resolution, depth of field and image volume under various combinations of focal length, aperture and target distance. Imaging of live zooplankton has been conducted to evaluate the performance of the system using realistic targets. Initial data indicate that the system meets performance expectations. ZOOVIS is capable of imaging the contents of a large volume of water (ml) at distances of 30-70 cm from the camera. Greater separation between the camera and target volume is feasible but has not yet been tested. Zooplankton ranging in size from 2-30 mm of a variety of opacities (opaque to almost completely transparent) are clearly visible in our test images. We plan to conduct completely immersive tank trials of the system at the Louisiana Universities Marine Consortium (LUMCON) facility in Cocodrie, La during early-winter and spring 2001. They will be followed by field trials at an offshore petroleum platform. MOCNESS comparisons will be conducted using a ship of opportunity.

WORK COMPLETED

Funding for this project was available in July, 1998 and the project is in its 26th month of operation. Work during the first year of the project focused on developing specifications for the ZOOVIS components and securing the system components.

Digital Camera

The core of ZOOVIS is a 4.19 megapixel digital camera (PixelVision BioXite 2K) capable of providing 12 bit monochrome images (4096 levels of gray) at 2 Hz (Fig. 1). The camera is equipped with a fast zoom lens (Tamron 28-105 mm f2.8) with optional teleconverters for higher magnifications. The camera is equipped with a multi-mode fiber-optic input (command/control) and output (RS422 serial data) interface.

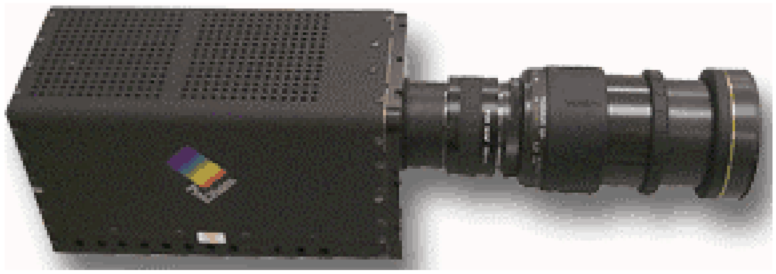

Figure 1. The BioXite camera equipped with zoom lens and a teleconverter

Structured Light Strobe

The digital camera's high resolution will allow us to image a substantially larger volume of water than is currently viewed by systems utilizing NTSC video. In order to eliminate the need to develop software to detect and reject out-of-focus targets, we opted to use a structured light source. By setting the depth of field of the lens to a range slightly greater than the width of the light sheet and centering the light sheet on the depth of field, all targets that are illuminated will be focused objects. Our strobe (Fig. 2) is a custom-built system designed by Seascan Inc., who also manufacturer the Video Plankton Recorder. The strobe is produces a collimated, 20 μsec light pulse with a width of 7 cm and a thickness of 3 cm. This will permit us to photograph volumes of up to approximately 596 ml (14.1 cm x 14.1 cm x 3 cm deep) in each image while maintaining a pixel density of 145 pixels cm^{-1}.

Figure 2. Strobed light sheet within pressure vessel

CTD

Our CTD is a SeaBird Electronics Model SBE19 equipped with a Wetlabs fluorometer and SeaStar transmissometer. We have interfaced an RS232 fiber-optic modem and multiplexor with the CTD so that data and control can be transmitted bidirectionally via one of the oceanographic cable's three fibers. A TrackPoint-compatible underwater acoustic beacon has been delivered and this will be placed on the underwater frame to assist with recovery in the event (hopefully unlikely) that the system requires recovery.

Communications and Power Supply

The underwater unit consists of four systems: camera, telemetry and power distribution, strobe and the CTD. The camera will be housed in its own canister, which is currently on order. Multimode fiber telemetry from the camera can is carried to a power supply/telemetry can where it is multiplexed and converted to single-mode prior to transmission to the surface. Serial data from the CTD is also sent to the telemetry can via conductive cable. Once there it is converted to a fiber-optic signal and multiplexed for transmission to the surface. Surface power is transmitted via the conductive elements in the cable to a multi-voltage power supply housed in the power supply/telemetry can. From there it is distributed to the camera, strobe and CTD.

Electro-Optical Cable, Winch and Slip-Ring Assembly

ZOOVIS is connected to the surface via a 300 m length of custom-built electro-optical cable consisting of three single-mode fibers and three shielded copper conductors surrounded by two contrahelically-wrapped kevlar strength members. The cable is wrapped in a polyurethane jacket. We have acquired a Sea-Mac Model 210 electro-hydraulic winch capable of paying out and hauling ZOOVIS at up to 1 m/sec. Electro-optical slip rings (Focal Technologies) have been installed on the winch.

RESULTS

All primary system components with the exceptions of the underwater pressure housings for the camera and power supply/ telemetry hardware have been acquired. The latter two items have been ordered along with the fiber-optic connectors required for completion of the cans. Bench-top testing of the system has been conducted and is nearing completion. Our fiber optic network is capable of handling the transmission of uncompressed full-resolution images at 2 Hz while controlling the and receiving data from the CTD.

We set out to design a system that could image a large volume of water while retaining sufficient resolution to identify small targets. Our results to date indicate that ZOOVIS is capable of meeting this performance goal (Fig. 3). Large image volumes (300-600 ml) retain sufficient detail to allow recognition of small and large targets. Tests of the system using live zooplankton suspended in

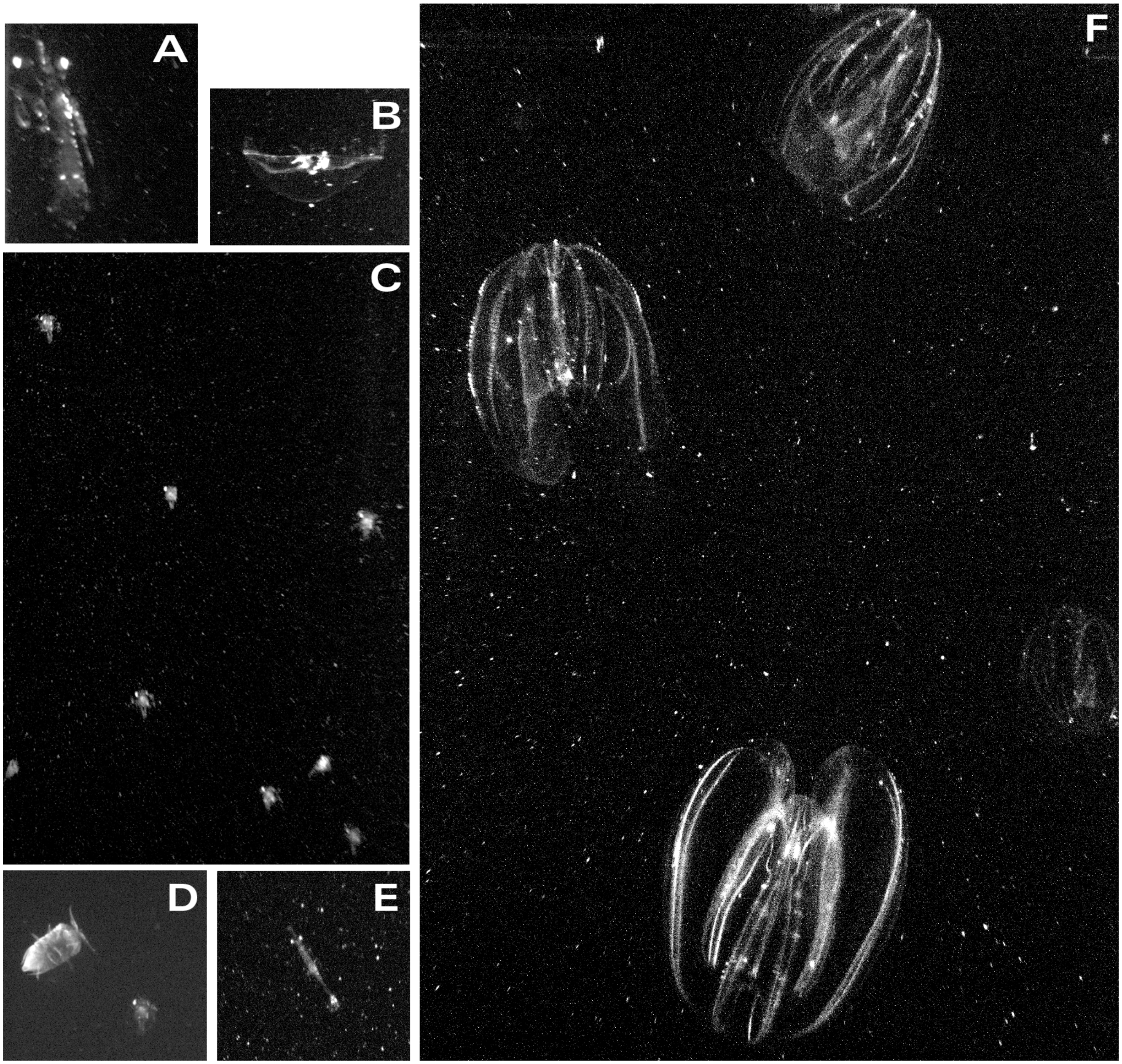

Figure 3. Composite of ZOOVIS images of live zooplankton in test tank. Each image contains a portion of the total image field of view. The volumes of the original uncropped images are indicated after each organism's identity in parentheses. A. 16 mm long stomatopod (mantis shrimp) larva (image volume = 355ml); B 11.5 mm wide medusa (image volume = 355ml); C portunid crab megalopae 1.2-1.8 mm wide (image volume = 334ml); D. 5.7 mm long isopod and 1.25 mm wide crab megalopa (image volume = 334 ml); E. 10.4 mm long postlarval penaeid shrimp (image volume = 598ml); F. Mnemiopsis ledyi ctenophores ranging in width from 14-23 mm (image volume = 502 ml).

transparent tissue culture flasks that were immersed in a large aquarium indicate that the system can image relatively transparent organisms such as ctenophores and stomatopod larvae within a large volume of water as well as organisms in the 1-2mm range (Fig. 3). The detail of such images is sufficiently high to permit identification and measurement. For example, the crab megalopae, penaeid shrimp postlarva and hydromedusa illustrated in Fig. 3 were all imaged in volumes of water that exceeded 300 ml. We are also interested in quantifying targets within the sub-millimeter range. Our next series of tests will utilize a smaller volume of approximately 75 ml (50 mm x 50 mm x 30 mm). With a theoretical pixel density of 41 pixels mm^{-1} we should be able to gather detailed images of copepods and other small organisms while still imaging the complete bodies of moderately large taxa.

The PixelView 3.2 software that we are currently using to acquire and view images appears to function well, however, Chris Schwehm is working on a more efficient software system for acquiring and displaying ZOOVIS data.

IMPACT/APPLICATIONS

This study will yield an instrument capable of imaging zooplankton-sized particles in waters to depths of 250 m while simultaneously collecting data on bio-physical parameters at comparable spatial scales. By coupling a high-resolution camera capable of sampling at up to 2 Hz, with a flexible zoom lens, we will be able to adjust the image volume for specific applications and different target size ranges. ZOOVIS will fill a niche between towed optical systems such as the Video Plankton Recorder and moored systems such as the autonomous vertically profiling plankton observatory. ZOOVIS will be a shipboard instrument capable of rapidly collecting vertical profiles within surveyed areas. Horizontal distances between casts will be controlled by the user and scaled to match the patch structure of features of interest. Interpolation between casts within depth strata will provide a mechanism for volumetrically rendering the distributions of taxa and environmental parameters.

Applications include, but are not limited to: zooplankton surveys, ground-truthing of high-frequency acoustic backscatter profiles, and determination of the distribution and size structure of biotic and abiotic particles in the oceans.

TRANSITIONS

ZOOVIS will be used in 2001 to collect data on the spatial and temporal variation in zooplankton distributions at a Gulf of Mexico petroleum platform. This study funded by the Minerals Management Service, is designed to identify trophic linkages between zooplankton and medium-sized pelagic fish predators at petroleum platforms. Mr. Sean Keenan is pursuing this study for his M.S. research at LSU.

ZOOVIS has been proposed as a system for ground-truthing acoustic data in a collaborative proposal submitted to ONR by the Institute of Ocean Sciences, Canada and LSU. This study will examine the relationship between steep topographic features and zooplankton distributions. The use of a profiling instrument such as ZOOVIS is well suited to surveys around abrupt vertical relief.

Dr. Amatzia Genin has invited us to use ZOOVIS to monitor zooplankton flux across a coral reef off Eilat, Israel during 2001 or 2002. In that application, we plan to moor the system over the reef and run the fiber optic cable directly to a shore-side laboratory.

ZOOVIS will be featured at the Louisiana Sea Grant Ocean Commotion on October 12, 2000. This one day event is designed to expose K-12 students to marine science. Students will be able to use ZOOVIS to estimate the abundance of fishes in a tank based on densities from individual images.

RELATED PROJECTS

Our instrument will provide data on the spatial variation of zooplankton abundance and the size distributions of small particles on vertical scales of less than one meter, and horizontal scales of tens to thousands of meters. Such data are an essential for ground-truthing acoustics data and constraining the estimation of biomass from multi-frequency acoustic backscatter data (inverse problem). One of the PI's (Benfield) is currently involved in NSF/GLOBEC research using an ONR-funded vehicle (BIOMAPER II) in the Gulf of Maine. In that study, zooplankton data are provided by a Video Plankton Recorder on BIOMAPER II and a MOCNESS. We have shown that optical data can be used to extract biomass data from acoustics (Benfield et al. 1998). With ZOOVIS, we will have a comparable ground-truthing capability for acoustic surveys in the Gulf of Mexico and other regions (including structurally complex areas where towed instruments may become fouled). Insights gained from comparisons of the patterns of zooplankton distributions in the shelf waters off New England and the Gulf of Mexico will help us to understand how zooplankton distributions and physical factors are related in coastal waters. Given the Navy's focus on littoral operations, this information will be useful for understanding and predicting spatial variation of sound-scattering organisms.

PUBLICATIONS

The design and preliminary results from ZOOVIS will be presented at the ASLO Aquatic Sciences Meeting in Albuquerque, NM during February 2001 (Benfield and Schwehm, Submitted). We plan to submit a manuscript describing the instrument shortly after that meeting.

REFERENCES

Benfield, M.C., P.H. Wiebe, T.K. Stanton, C.S. Davis, S.M. Gallager and C.H. Greene. 1998. Estimating the spatial distribution of zooplankton biomass by combining Video Plankton Recorder and single-frequency acoustic data. *Deep-Sea Research Part II,* 45: 1175–1199.

Benfield, M.C. and C. Schwehm. Submitted. ZOOVIS: A high resolution digital camera system for quantifying zooplankton abundance and environmental data. Poster submitted for presentation at the ASLO Aquatic Sciences Meeting, Albuquerque, NM, February 2001.